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DIASTROPHISM AND THE FORMATIVE PROCESSES. IX[1]

A SPECIFIC MODE OF SELF-PROMOTION OF PERIODIC DIASTROPHISM

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In the opinion of many students of diastrophism, world-wide deformative movements tend toward periodicity in the very nature of the case; more or less oscillation between relatively active and quiescent stages would arise without any special aid from accessory agencies. But in the natural order of things secondary movements often spring from the primary actions and abet them. It is the purpose of this note to call attention to a specific form of secondary action by which the oscillations between the active phases of deformation and the intervening quiescent stages are accentuated and the periodicity of major diastrophism emphasized.

When world-wide diastrophism follows a period of general base-leveling and wide sea-transgression the diastrophic movement is logically regarded as springing from accumulated earth-stresses of such a nature as to give rise to relative downward movements of the sub-oceanic segments and relative upward movements in the continents in spite of whatever burden of epicontinental waters

[1] For previous article (Part VIII) of this series see the *Journal of Geology* for July-August, 1914.

the latter may bear. The spontaneous transfer of the epicontinental waters to the ocean basins, thereby unloading the continents and further loading the basins, adds force to the diastrophic process and constitutes a specific example of self-instituted promotion of periodicity. The periodicity is emphasized because this action tends to push the diastrophic movements beyond what would otherwise have been their limits, and this results in an enhanced degree of easement of the original body-stresses and by so doing more effectively prepares the way for a new period of quiescence, base-leveling, and sea-transgression.

This will become quite clear by following in detail the history of a typical case, if the interpretation is guided by that phase of the doctrine of periodic diastrophism which is specifically appropriate to a solid elastico-rigid earth. In strict consistency with such an earth isostatic readjustments are assumed to take place by wedging and not by undertow beneath a floating crust. This type of isostatic adjustment is analogous to the familiar balancing of weight against weight on a pair of scales and is clearly distinguishable in mode, though not in principle, from the more common concept of flotation which has for its analogue the hydrometer.

1. Let it be assumed that the continental platforms, including the sea shelves, occupy one-third of the earth's surface and the true ocean basins—neglecting the continental shelves—the remaining two-thirds. For a typical stage from which to start let it be supposed that as the result of a general diastrophic movement the oceans have recently been withdrawn into the abysmal basins so that the whole surface of the continental platforms, including the continental shelves, shall have become land and the terrace edge of the shelf shall coincide with the oceanic shore line. Some such condition seems to have been realized in late Tertiary times. To add concreteness let the mean measure of continental protrusion above the lowered sea-level, including the shelf depth, be 900 m. and the mean abysmal depth 5,000 m.

2. Now let a typical period of relative freedom from general diastrophic movement ensue. Such relatively quiescent periods are implied by general base-leveling and wide sea-transgression. Their periodic recurrence seems to be substantiated by the great

overmantlings of large fractions of the face of the continents by marine deposits in Ordovician, Silurian, Cretaceous, Eocene, and other periods. Without such relatively static periods general base-leveling seems impossible. Theoretically such periods are assignable to previous effective easement of all differential stresses of the higher order. Such easement is really implied in the emergent state of the continents and the reciprocal depressed state of the great basins just assumed as the first stage in the case we are following.

3. During this relatively quiescent period let the normal processes of denudation and deposition follow their inevitable courses, unloading the continents and loading the ocean basins, while the sea slowly encroaches upon the borders of the continental platforms until, let us say, 30 per cent or 40 per cent of the surface of the continental platforms is overlipped by the thin edges of the oceans. Among the incidents of this period the following may be noted:

a) In the early stages the bordering belts of the continents, as a rule, suffered greater relative unloading than the interiors because they had been most affected, on the average, by the preceding diastrophism, and their drainage gradients were higher than those of the more remote interior and the denudation more rapid, while the direct action of the cutting edge of the sea added its effects.

b) Later in the period, as the sea crept forward over the widening shelf and gave rise to the deposition of top-set beds upon the surface of the shelf, the weight of these deposits compensated in some measure for the previous unloading, while the rise of the sea-level itself, due to the sediment carried into the oceans, added some further compensation by an increasing burden of sea-water.

c) The mechanical sediments from the land, beside lodging on the sea-shelf as top-set beds, accumulated predominantly around the shelf-edge as fore-set beds, while subordinately they were carried farther out to sea and settled widely over the ocean bottom.

d) The solvent material was at first distributed by currents and diffusion with approximate uniformity throughout the oceanic waters, but later a part of it was extracted by organic and other agencies and deposited wherever chance overtook it, often far from its point of origin on the continent.

It is worth observing that the highly carbonated state of the abysmal and polar waters of the present subglacial period leads to a large measure of solution of the calcareous relics that fall from the pelagic plankton toward the abysmal depths, and this greatly limits current oceanic deposits; but this specially solvent state of the abysmal waters probably did not obtain during the mild climates typical of times of wide sea-transgression. Hence a wider and thicker abysmal deposit may be postulated for those times.

4. Now at a critical stage of this progress when 30 per cent or 40 per cent of the surface of the continental platforms had become covered by the transgressing shelf-seas, let it be assumed that the loading and unloading had developed sufficient differential stresses in the earth-body to start easement movements by the depression of the weighted suboceanic segments on the one hand and the relative elevation of the denuded continental segments on the other. These reciprocal movements would be followed by a flow of water from the rising continental shelves to the sinking ocean basins. This shift of burden from one side of the equation to the other would tend to intensify the diastrophic movement. If this new emergence returns to a stage comparable with that assumed at the outset, all the water-burden upon the sea-shelf, a matter of perhaps 300 lbs. or so per square inch, averaged for the whole shelf area, will have been transferred in this unrestrained way to the abysmal basins, where it will be an added burden of equal value, though much more widely and uniformly distributed. In more general terms this may amount to a mean unburdening of the continental area, considered as a whole, to the extent of about 50 lbs. per square inch and a simultaneous mean loading of the whole oceanic area of about 25 lbs. per square inch.

A concurrent enhancement of effect will arise from the ease with which the rock mantle accumulated during the base-leveling stage—as well as the soft sediments on the face of the sea-shelf—will be eroded and carried down to the borders of the depressed ocean as the continental elevation advances.

It thus appears that such a general diastrophic movement, in the course of its own normal line of action, brings into play an easy and prompt shifting of load of a special type that tends to acceler-

ate the primary movement and give it a cumulative value. This tends to push the movement to a maximum the better to prepare the way for a new quiescent period.

Such cumulative periodicity, both primary and enhanced, seems not only consistent with a solid elastic earth but an inevitable consequence of the elastic rigidity of such an earth. As already remarked, the normal mode of isostatic adjustment in such an earth is thought to be wedging action in the form of movements on the part of its constituent tapering prisms, conical, pyramidal, or otherwise, in response to the varying stresses imposed on them. Facilities for such movements are presumed to be provided by vertical schistosity developed in the tracts where the differential stresses are greatest, and by the very stresses that actuate the deep diastrophic movements. So originated they should reach to whatever depths may be seriously affected by differential stresses of an order requiring readjustment. No undertow in a hypothetical mobile substratum is necessarily involved and none is postulated. The weighted parts wedge down and the unloaded parts are wedged up until the differential gravitative stresses are essentially equated and an isostatic state reached. Movement in a rigid earth of course is not presumed to take place until stresses have accumulated to a degree adequate to force it and hence the relatively quiescent stages. The quiescent stages occupied in such stress-accumulation are interpreted as constituting the periods marked by base-leveling and sea-transgression, appropriate conditions for which are thus provided. General isostatic readjustments are of course interpreted as synonymous with general diastrophic movements and so are regarded as equally periodic. As the present epoch has been preceded by great diastrophic movements, the earth body is presumably now in a stage of approximate isostatic adjustment, as implied by geodetic evidences.